MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2022/2023 (TERM ID 2220)

EME1166 – MATERIAL SCIENCE

(ME)

14 JULY 2023
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question Paper consists of seven pages including the cover page and appendix.
2. Answer ALL four questions. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].
3. Write all your answers in the Answer Booklet provided.

Question 1

(a) Write the electron configuration for the following

(i) Copper (Z = 29) **[2 marks]**
(ii) Oxygen (Z = 8) **[2 marks]**
(iii) Tin (Z = 50) **[2 marks]**

State the types of bonding that would be expected when copper is bonded with oxygen and tin, respectively. **[2 marks]**

(b) Potassium has a density of 0.89 g/cm^3 and atomic mass of 39.098 g/mol. Determine the crystal structure and atomic radius of Potassium given that it has a lattice constant of 0.533 nm. **[7 marks]**

(c) Sketch the following direction vector and crystal plane in unit cube

(i) $[2\bar{1}3]$ **[2 marks]**
(ii) $(2\bar{1}3)$ **[2 marks]**

(d) Is the linear atomic density in the $[0\bar{1}\bar{1}]$ direction of a BCC crystal lattice the same as that of a FCC crystal lattice? Justify your answer with calculations.

[6 marks]

Continued...

Question 2

(a) With the aid of sketches, describe the "Schottky imperfection" and "Frenkel imperfection". **[6 marks]**

(b) Calculate the vacancy fraction at 450 °C in aluminium. Assume the energy of vacancy formation is 0.62 eV/atom and Boltzmann's constant is 8.62×10^{-5} eV/K. **[4 marks]**

(c) Determine the ASTM grain size number if 40 grains per square centimeter are measured at a magnification of 200×. Based on your calculated answer, identify if the material is coarse-grained, medium-grained, fine-grained or ultrafine-grained. **[7 marks]**

(d) A steel gear can be hardened by carburization at 950 °C. Assume the carbon concentration is 1.5 kg/m^3 at the gear surface and 1.2 kg/m^3 at 0.5 mm beneath the surface. Determine the steady-state diffusion flux of carbon atoms into the steel. Given the temperature-dependent proportionality constant is 18×10^{-6} m^2/s and activation energy is 145 kJ/mol. **[8 marks]**

Continued...

Question 3

(a) A 10 mm diameter cylindrical rod with a length of 100 mm is subjected to a tensile stress of 150 MPa along its longitudinal axis. The rod is made of material that has an modulus elasticity of 120 GPa, modulus of resilience of 0.5 MPa and a Poisson's ratio of 0.4. Determine

(i) The yielding stress of the material **[2 marks]**
(ii) The change in volume of the cylindrical rod **[11 marks]**

Will the change in volume be permanent after the load is released? Explain your answer. **[2 marks]**

(b) Sketch the stress-strain curves for the two modes of fracture. Briefly describe two main differences between them. **[6 marks]**

(c) Define fatigue. **[2 marks]**

(d) Define creep. **[2 marks]**

Continued...

Question 4

(a) Briefly describe the eutectic and eutectoid reactions in a phase diagram.

[4 marks]

(b) An iron-carbon alloy containing 1.25 wt% C, is cooled to below the eutectoid temperature as indicated in **Figure 4(b)**. Determine:

(i) The weight fraction of ferrite and cementite in the iron-carbon alloy

[6 marks]

(ii) The mass of ferrite and cementite formed in the 1.5 kg of iron-carbon alloy

[4 marks]

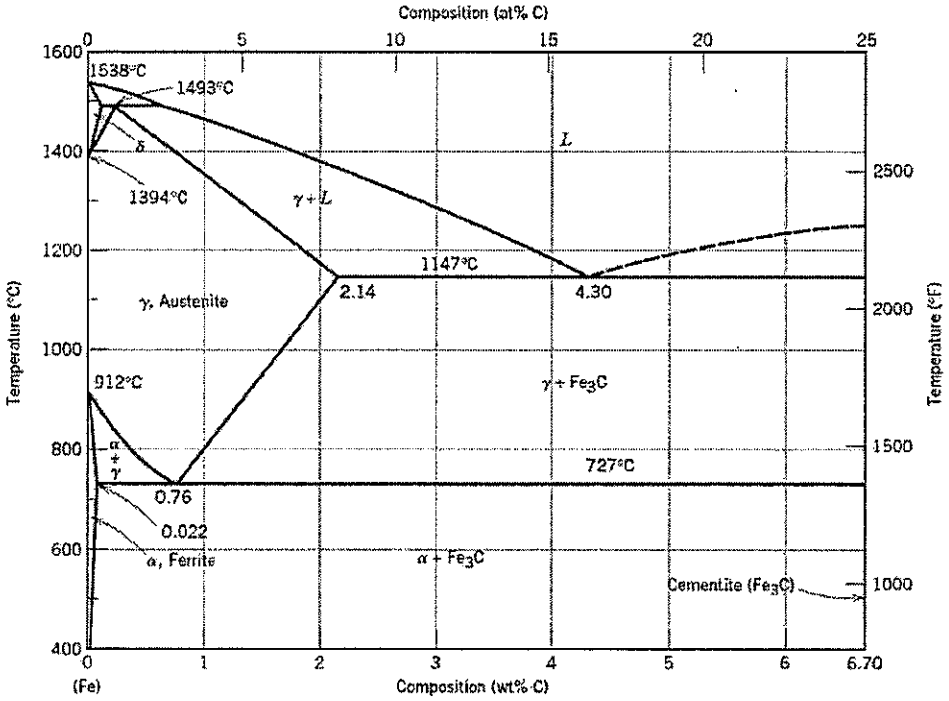

Figure 4(b)

Continued...

(c) Predict the possible transformation of austenite after undergoing the following processes:

(i) Slow cool **[1 mark]**
(ii) Moderate cool **[1 mark]**
(iii) Rapid quench **[1 mark]**

(d) With reference to **Figure 4(d)**, approximate the desirable temperature to heat up the 0.6 wt% C iron-carbon alloy during the following treatments:

(i) Normalizing **[1 mark]**
(ii) Full annealing **[1 mark]**

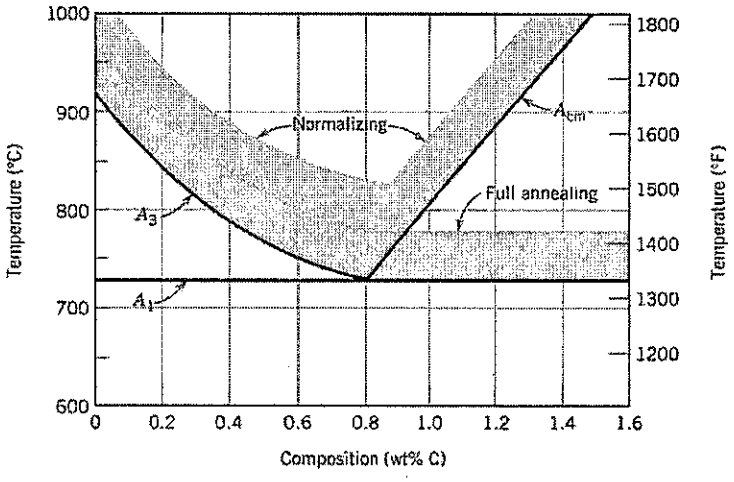

Figure 4(d)

Briefly describe the three main differences between the normalizing and full annealing treatments. **[6 marks]**

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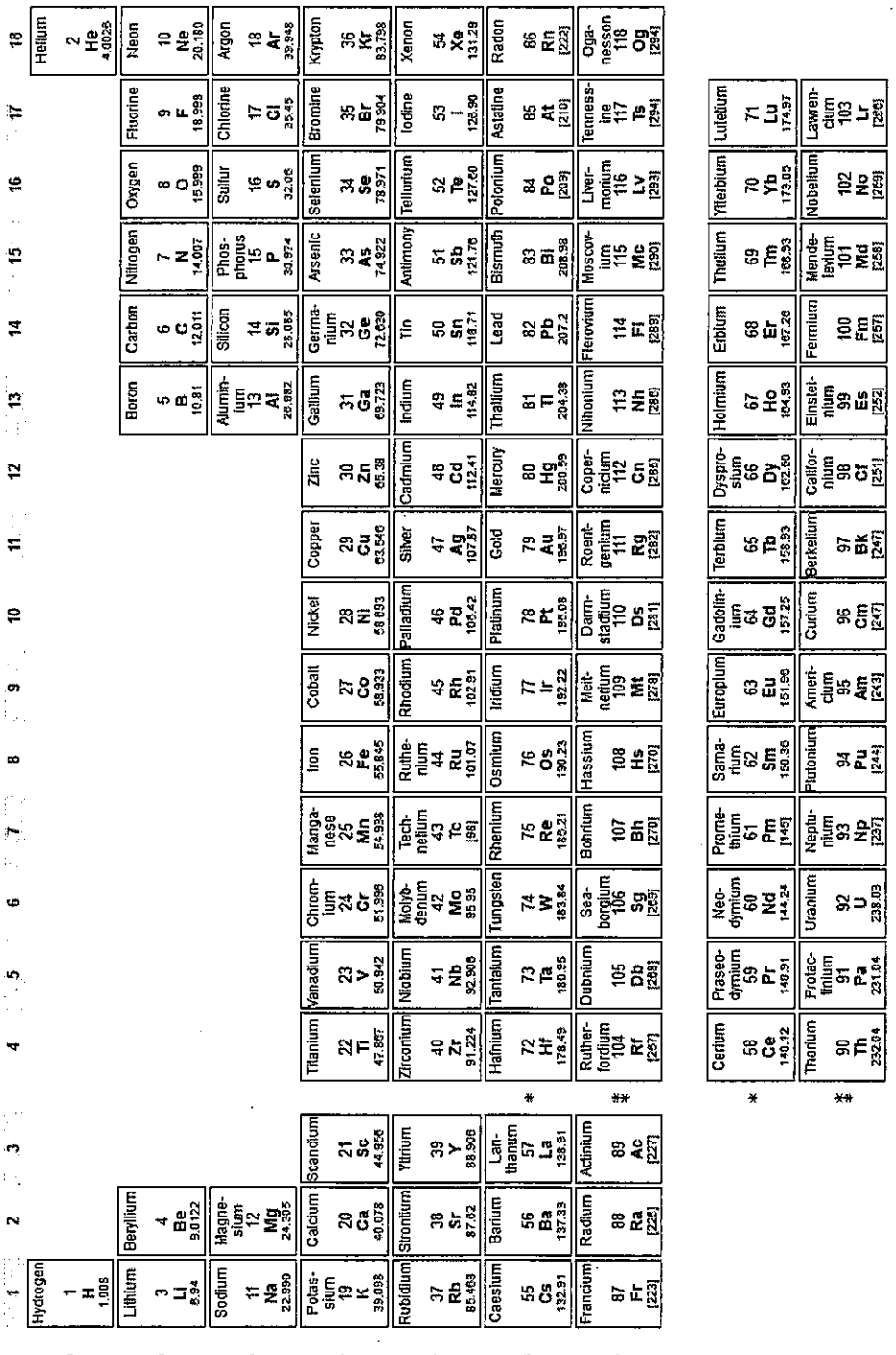
Appendix A: Periodic Table of Elements


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
① ② ③ ④ ⑤ ⑥ ⑦
Hydrogen 1 H 1.008
Helium 2 He 4.0026
Lithium 3 Li 6.94
Beryllium 4 Be 9.0122
Boron 5 B 10.81
Carbon 6 C 12.011
Nitrogen 7 N 14.007
Oxygen 8 O 15.999
Fluorine 9 F 18.998
Neon 10 Ne 20.180
Sodium 11 Na 22.990
Magnesium 12 Mg 24.305
Aluminium 13 Al 26.982
Silicon 14 Si 28.085
Phosphorus 15 P 30.974
Sulfur 16 S 32.06
Chlorine 17 Cl 35.45
Argon 18 Ar 39.948
Potassium 19 K 39.098
Calcium 20 Ca 40.078
Scandium 21 Sc 44.956
Titanium 22 Ti 47.867
Vanadium 23 V 50.942
Chromium 24 Cr 51.996
Manganese 25 Mn 54.938
Iron 26 Fe 55.845
Cobalt 27 Co 58.933
Nickel 28 Ni 58.693
Copper 29 Cu 63.546
Zinc 30 Zn 65.38
Gallium 31 Ga 69.723
Germanium 32 Ge 72.630
Arsenic 33 As 74.922
Selenium 34 Se 78.971
Bromine 35 Br 79.904
Krypton 36 Kr 83.798
Rubidium 37 Rb 85.468
Strontium 38 Sr 87.62
Yttrium 39 Y 88.906
Zirconium 40 Zr 91.224
Niobium 41 Nb 92.906
Molybdenum 42 Mo 95.95
Technetium 43 Tc [98]
Ruthenium 44 Ru 101.07
Rhodium 45 Rh 102.91
Palladium 46 Pd 106.42
Silver 47 Ag 107.87
Cadmium 48 Cd 112.41
Indium 49 In 114.82
Tin 50 Sn 118.71
Antimony 51 Sb 121.76
Tellurium 52 Te 127.60
Iodine 53 I 126.90
Xenon 54 Xe 131.29
Caesium 55 Cs 132.91
Barium 56 Ba 137.33
Lanthanum 57 La 138.91
Hafnium 72 Hf 178.49
Tantalum 73 Ta 180.95
Tungsten 74 W 183.84
Rhenium 75 Re 186.21
Osmium 76 Os 190.23
Iridium 77 Ir 192.22
Platinum 78 Pt 195.08
Gold 79 Au 196.97
Mercury 80 Hg 200.59
Thallium 81 Tl 204.38
Lead 82 Pb 207.2
Bismuth 83 Bi 208.98
Polonium 84 Po [209]
Astatine 85 At [210]
Radon 86 Rn [222]
Francium 87 Fr [223]
Radium 88 Ra [226]
Actinium 89 Ac [227]
Rutherfordium 104 Rf [267]
Dubnium 105 Db [268]
Seaborgium 106 Sg [269]
Bohrium 107 Bh [270]
Hassium 108 Hs [270]
Meitnerium 109 Mt [278]
Darmstadtium 110 Ds [281]
Roentgenium 111 Rg [282]
Copernicium 112 Cn [285]
Nihonium 113 Nh [286]
Flerovium 114 Fl [289]
Moscovium 115 Mc [290]
Livermorium 116 Lv [293]
Tennessine 117 Ts [294]
Oganesson 118 Og [294]
Cerium 58 Ce 140.12
Praseodymium 59 Pr 140.91
Neodymium 60 Nd 144.24
Promethium 61 Pm [145]
Samarium 62 Sm 150.36
Europium 63 Eu 151.96
Gadolinium 64 Gd 157.25
Terbium 65 Tb 158.93
Dysprosium 66 Dy 162.50
Holmium 67 Ho 164.93
Erbium 68 Er 167.26
Thulium 69 Tm 168.93
Ytterbium 70 Yb 173.05
Lutetium 71 Lu 174.97
Thorium 90 Th 232.04
Protactinium 91 Pa 231.04
Uranium 92 U 238.03
Neptunium 93 Np [237]
Plutonium 94 Pu [244]
Americium 95 Am [243]
Curium 96 Cm [247]
Berkelium 97 Bk [247]
Californium 98 Cf [251]
Einsteinium 99 Es [252]
Fermium 100 Fm [257]
Mendelevium 101 Md [258]
Nobelium 102 No [259]
Lawrencium 103 Lr [266]
* Lanthanoids
** Actinoids

End of Paper